Politics of Global Competition in the Semiconductor Industry

Jeffrey A. Hart

Introduction

Semiconductors are relatively new products which are used in a wide variety of electronic devices. Semiconductors "are materials (such as silicon, germanium, or gallium arsenide) whose electrical property is to act under certain conditions as insulators and other conditions as conductors."[1] Semiconductors have a wide variety of types, ranging from the simplest diodes and transistors to the most complex integrated circuits, and uses. Currently, the main uses of semiconductors are in computers, telecommunication equipment, office automation, and consumer electronics. In the next decade, a large portion of the increase in demand for semiconductors will come from new applications in industrial robots, automobiles, and advanced weaponry.

The semiconductor industry has the same centrality for the current wave of industrial innovation that the steel and automotive industries had in their time of glory. Computers, telecommunications, and robotics are dynamic high-technology industries, but they would not be so dynamic had there not been an almost incredible surge in innovation in the semiconductor industry. Technological and market change in microelectronics has been very impressive. Each year, a slew of new devices is introduced to the market, complementing and sometimes displacing the demand for older products. The very rapid growth in demand for semiconductor products fostered an image of endless bounty, at least until the first recessionary periods in the early

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[1] Giovanni Dosi, Technical Change and Survival: Europe's Semiconductor Industry (Brighton: Sussex European Research Center, 1981), p. 1.

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1980s, which led to political advocacy of high technology as a solution to all economic ills.

In 1980, the urban affairs panel of the President's Commission for a National Agenda for the Eighties shocked the country with its recommendation that the movement of businesses and people from the snowbelt (later called the "rustbelt") to the sunbelt was a healthy phenomenon that did not require governmental policies aimed at stauching the flow. The "Atari Democrats" played a prominent role in the 1984 U.S. presidential elections, providing support to the candidacy of Gary Hart in the Democratic Party. In Japan, MITI's *Vision for the Eighties* document recommended that Japan begin the transition from an economy dependent on heavy manufacturing to one which could take advantage of the dynamism of information technology.[2] An organization was established for the promotion of "softnomics"—a new economy based on information technology. In France, intellectuals like Simon Nora, Alain Minc, and Jean-Jacques Servan-Schreiber have been advocating a societal effort to adapt quickly to changes in information technology.[3] While such groups will change their names and composition over time, they will be with us for some time to come because the dynamism of the new industries has created a new set of political interests which are bound to be represented in the political arena.

Not all of us dream of living in Silicon Valley, the relatively small part of California stretching from the San Francisco Bay to Big Sur and the Santa Clara Mountains. According to recent portraits of the region, it suffers from expensive and low-quality housing, insufficient access to cultural amenities, smog, family instabilities and other ills of rapid growth.[4] But Silicon Valley still represents the ideal of high growth, high technology culture. The semiconductor firms located in Silicon Valley are noteworthy for their garden-like surroundings, plants with daycare centers and relatively pleasant work areas, and

their preference for nonunionized workers. The typical employee of such a plant would receive quite a handsome salary, live in a suburban ranch-style house within commuting distance (which could be 50-60 miles in California), and, thanks to recurring labor shortages, might have moved from one firm to another at least once in search of better benefits. Perhaps most importantly to Americans, it represents the continuation of the American dream of enriching oneself through entrepreneurial activities.

The problems of Silicon Valley, while very real, are greatly envied by others because they are problems of growth rather than problems of stagnation. A large number of local and regional governments around the world have implemented policies to entice high technology firms to locate nearby in hopes that they may form the basis for other silicon valleys. In Massachusetts, Boston is ringed by a number of computer and software firms on Route 128. In the United Kingdom, around Edinborough, there are a cluster of semiconductor and computer firms—Ferranti, INMOS, NEC, National Semiconductor—in an area not so jokingly referred to as "silicon glen." In Oregon and Washington, there is a "silicon forest" Florida has its 'silicon groves."

While the development of replicas of the original Silicon Valley is cause for hope among the more depressed regions, it is unlikely that there will be a very large number of such communities. The semiconductor industry seems to thrive on density, partly because, in industries highly dependent on the flow of information, face-to-face communications and the proximity of contractors and subcontractors is very important. Just as it is unlikely that there will be a large number of financial centers like New York, London, and Hong Kong, the prospect for thousands of silicon valleys springing up in the near future is quite limited. Nevertheless, the technology associated with the semiconductor industry is likely to change the way people live in all highly industrialized regions because it makes new kinds of manufacturing processes possible.

The Effects of Semiconductor Technology on Manufacturing

Semiconductor technology is quite well suited for easy incorporation into process technologies which speed up or reduce the costs of manufacturing while using less labor. These technologies are not

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[2] "Japan's Strategy for the Eighties," special issue of *Business Week*, (December 14, 1981).

[3] Simon Nora and Alain Minc, *The Computerization of Society* (Cambridge, MA: MIT Press, 1981); Alain Minc, *L'apres crise est commence* (Paris: Gallimard, 1982); Jean-Jacques Servan-Schreiber, *The World Challenge*.

[4] Peter Hall and Ann Markusen (eds.), *Silicon Landscapes* (Winchester, MA: Allen and Unwin, 1985).

much more expensive than the old manufacturing technologies, especially once they have become so common as to be available in standardized versions, and can be bought "off the shelf" with few modifications needed for the specific needs of the manufacturer. Thus, some argue that not only does the technology offer the prospect of greater regional disparities, it also might lead to a "deskilling" of industrial labor, reinforcing the decline in the political influence of organized labor which has been caused by reductions in employment in traditional industries.[5]

The overall picture, however, need not be gloomy. Clearly, a new wave of innovation is underway. Each previous wave of innovation created new forms of wealth and made possible higher standards of living through wage increases made possible by higher productivity of all factors of production. It is possible that this wave of innovation will end with people being able to choose a greater variety of living arrangements from the highly urbanized to the semi-rural, while still being able to participate fully in the national and even global economy. They may be able to buy all the products they currently enjoy at much lower costs. Those without industrial employment may be able to find remunerative jobs outside of manufacturing or find other means of self-fulfillment than selling their labor for wages. This, of course, is the utopia implied in the literature on the "post-industrial" society.[6]

The change in manufacturing processes brings with it the potential fot new arrangements for the organization of the work place. Even though microprocessor based manufacturing could lead to the adoption of technologies which reduce the demand for skilled labor in certain areas—e.g. machining—it will also increase the demand of skills in other areas—e.g. programming and maintenance. This technology increases the desirability of fostering good relations between management, engineering and line production personel, in order to take full advantage of the flexibilities it allows in production processes. Thus, an enlightened set of management and labor leaders might work together to establish a generally more favorable work environment if they are made fully aware of the competitive advantages of doing so. This leads authors like Charles Sabel and Michael Piore to suggest that we are on the edge of new era of industrialism, one which may be more humane than the previous one.[7]

Reality is likely to produce something in between the utopian world just described and the highly polarized societies that the critics of the new technology fear. Studies of the implementation of new manufacturing process technologies to date suggest that the positive benefits of the new technology are more likely to be realized in plants where the more expensive and more customized products (e.g. luxury automobiles) are produced; in plants where low-priced standardized goods are produced, the new technology tends to be used to increase the ability of management to control the pace of production at the expense of a more hassled work force.[8] The key question, therefore, is to what extent will the consumers of the future demand customized as opposed to standardized goods. Piore and Sabel base their optimism on the belief that competitive pressure will force almost all producers to move toward customization, but there will still be trade-offs to be made between mass and customized production because there will continue to be economies of production connected with long runs of standardized products. As long as consumers continue to buy certain goods primarily on the basis of price (most clothing, small appliances, basic automobiles, etc.), they will continue to satisfy themselves with standardized products.

Regardless of what happens in markets for mass consumer items, developments in the semiconductor industry will be crucial to the competitiveness of a wide variety of related industries. Policy makers in all the industrial countries are aware of the dependence of their mature and high technology industries on the performance of their domestic semiconductor firms. Thus, while problems with trade in semiconductors have not yet created the sorts of bitter disputes increasingly seen in the more mature industries, like steel and

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[5] David F. Noble, *Forces of Production* (New York: Knopf, 1985); Harley Shaiken, *Work Transformed* (New York: Holt, Rinehart and Winston, 1985); Barry Bluestone and Bennett harrison, *The De-Industrialization of America* (New York: Basic Books, 1982).

[6] Daniel Bell, *The Coming of Post-Industrial Society* (New York: Harper Colophon Books, 1973).

[7] Charles Sabel, *Work and Politics* (New York: Cambridge University press, 1982); Michael Piore and Charles Sabel, *The Second Industrial Divide* (New York: Basic Books, 1984). The argument presented in the more popular work by Robert Reich, *The New American Frontier* (New York: New York Times, 1983), was strongly influenced by Charles Sabel's pioneering research.

[8] Shaiken, *op. cit.*

automobiles, policy makers around the world are concerned about the possibility that domestic firms may not be able to compete successfully under existing arrangements and are examining a variety of measures to alter those arrangements to the advantage of domestic firms. There are clear signs, especially in U.S.-Japanese relations, of growing tensions connected with imbalances in trade in semiconductors which will be review below.

Below the focus will be on the way in which global and regional markets for semiconductors are organized, what firms are in those markets and what strategies they have adopted to deal with rapid change. That description of the markets will be followed by a brief discussion of the recent trade disputes over semiconductors and an overview of the policies adopted in the United States, Japan and Europe to compensate for perceived disadvantages of domestic firms.

The Technological Evolution of the Semiconductor Industry

The semiconductor industry is a relatively new industry, beginning with the invention of the transistor by a group of researchers at Bell Laboratories in 1947-8. The production of semiconductors for commercial markets did not begin until the mid 1950s.[9] The industry has been characterized since that date by very rapid changes in technology. This rapid pace of change has produced two major effects: 1) intense competition among firms for the new markets opened up by technological innovations and 2) a proliferation of submarkets within the overall semiconductor market as the circuitry on each "chip" grew more complex.

Semiconductors existed prior to transistors in the form of diodes, simple electronic components which allowed a one-way flow of current through a circuit. The invention of the transistor meant that semiconductors could replace the workhorse of most electronic devices, the vacuum tube. Vacuum tubes were used to modify or amplify signals passing through a circuit. Transistors were able to do these same jobs using less space and less power than vacuum tubes.

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[9] For histories of the early days of the industry see Ernest Braun and Stuart Macdonald, *Revolution in Miniature* 2nd Edition (New York: Cambridge University Press, 1982); John E. Tilton, *International Diffusion of Technology: the Case of Semiconductors* (Washington, D.C.:Brookings Institution, 1971).

The producers of electronic products quickly realized the advantages of transistors over vacuum tubes, especially as the prices of transistors dropped far below the price of the average vacuum tube, and began to incorporate them into the design of downstream products.

In the mid 1960s, a few small firms began to market a new product: a semiconductor device which combined a number of transistors on the same piece of silicon and linked them together by a simple circuit etched into the surface of the silicon. This device was the beginning of "integrated circuits." All semiconductors may be considered to fall into one of two categories: discrete devices (e.g. single transistors) and integrated circuits. The integrated circuit, as soon as it was introduced, began to eat into the markets for discrete devices. By the early 1980s, integrated circuits accounted for over 80 percent of the market for semiconductors.

The earliest integrated circuits were "bipolar" circuits: i.e., the silicon was either etched or left untouched. An alternative production process soon arose which created a variety of layers on the surface of the silicon prior to etching, allowing for somewhat more complex types of circuitry. This was the "MOS" or Metal Oxide Semiconductor circuit. More recently, a third type of circuit was developed, the "CMOS" circuit. CMOS devices used less power than MOS and can be made to retain information even when the device is switched off by including a small battery current. Even though CMOS is more expensive than MOS, the greater portability of CMOS products creates a market niche for them. Calculators, hand-held video games, lap-top portable computers, and other similar products are made with CMOS circuits.

The most important types of integrated circuits, aside from the differences among bipolar, MOS and CMOS, are: 1) logic circuits, 2) microprocessors, 3) random access memories (RAMs), 4) read only memories (ROMs), and 5) custom circuits. Logic circuits perform the simple logical tasks required in the switching of telephone circuits, for example. Microprocessors are basically computers on a chip but lacking sufficient memory or ability to control peripheral devices to perform all the tasks of computers. They do all the arithmetic and bit manipulation required for computing up to the point where one needs more memory or to input or output data. Read only memories are memories that can only be read, used to generate information for inputs of various sorts. ROMs are frequently used to store instructions, or even entire software programs, for use by other integrated circuits. More recently two subclasses of ROMs have appeared: EPROMs (Eraseable/Programmable ROMs), and EEPROMs (Electronically Eraseable/Programmable ROMs). Unlike earlier ROMs, these allow you to change the information that is on a ROM. RAMs are needed for computing because they can store information as long as the current is on and make it possible to read this information as well. For "dynamic" RAMs, however, when you turn the current off, you lose this information, thus the need for devices like ROMs and slower forms of fixed storage such as tape drives, cassette recorders, or the newer "floppy diskettes" and "hard disk drives" which are becoming omnipresent with the proliferation of microcomputers. Custom circuits are all other integrated circuits, a residual category that includes exotic circuits of the last several years (such as "gate arrays"). More will be said about custom circuits when we turn to an assessment of the competitive environment of the near future.

The table below shows how RAMs and microprocessors have evolved since 1970, based on the year of market introduction. RAMs grow in density from 1K (1,000) bytes of storage in 1970 to 256K in 1984 by steady doublings of capacity. Microprocessors evolve toward an ability to process larger and larger bytes (a byte is a collection of bits where a bit is a basic off-or-on unit of information), and thus capable of making numerical calculations of greater accuracy and performing more and more complex tasks.

Table 1. Year of Introduction of RAM Devices and Microprocessors

Year	Type of RAM	Type of Microprocessor
1970	1K	
1973		calculator
1974	4K	
1976		8-bit
1977	16K	
1979	64K	16-bit
1984	256K	32-bit

Source: *Trade in High-Technology Products: Industrial Structure and Government Policies* (Paris: OECD, 1984), p. 6.

The combination of increased memory capacity and size of bites, together with steady reduction in the price per bit of memory and per instruction performed by a microprocessor, reduces the difference between what a small computer can do and what a hugh mainframe computer used to do. In other words, over time, there has been a large increase in the amount of computing power one can buy for a dollar. In addition, the amount of raw computing power per dollar has decreased most rapidly for the smallest computers. Only in very large organizations with thousands of users are the per user costs lower for large mainframe computers that they are for mini- or microcomputers. This technological evolution has very interesting implications beyond the ones already raised in the introduction. Perhaps the most important is the increased potential for decentralizing information processing, for allowing any small firm or even an individual with an average income to purchase almost as much computing power as is available to very large corporations. Whether this potential will be realized is not, however, the subject of this chapter or of this book. Here we will be concerned primarily with the short and medium term implications of the new technologies for the semiconductor industry and, consequently, for the relations among the industrialized countries.

The Structure of World Production

In 1984, world production of semiconductors was estimated to be around $26 billion and of integrated circuits (a special kind of semiconductor device explained in the previous section) $19 billion.

Table 2. World Semiconductor Production, By Region, 1983-6
(in Billions of Dollars)

Year	U.S.	Europe	Japan	Rest	World
1983	7.8	3.0	5.5	1.0	17.3
1984	11.9	4.7	8.1	1.7	26.3
1985	8.3	4.5	7.6	1.2	21.6
1986p	10.6	8.7	4.8	1.4	25.5

Source: World Semiconductor Trade Statistics (WSTS) data of the Semiconductor Industry Association (SIA) of the United States as cited in *Electronic News* issues of September 30, 1985 (p. 6) and October 1, 1984 (p. 40).

Between 1978 and 1983, world production of integrated circuits grew annually at an average rate of percent; integrated circuits grew at a rate of percent (see Table 3 below).

Table 3. World Production of Integrated Circuits, 1978-83

(millions of dollars)

A. As Estimated by Dataquest

Year	USA	Europe	Japan	Rest	Total
1978	4582	453	1195	382	6712
1979	6681	600	1750	675	9706
1980	9055	710	2450	130	12345
1981	8950	790	2590	160	12490
1982	9300	790	3130	160	13380
1983est	10450	855	3910	190	15405

Note: These statistics include captive production of integrated circuits by large computer firms like IBM.

B. As Estimated by Benn Publications

Year	USA	Europe	Japan	Rest	Total
1983	6137	2275	3265	842	12519
1984	9390	3322	5126	1289	19129
1985set	10329	3521	5536	1397	20782
1986p	11981	3978	6533	1619	24111

Source: Dataquest as cited in *Trade in High-Technology Products: Industrial Structure and Government Policies* (Paris: OECD, 1984), p. 110; Benn data as published in *Profile of the Worldwide Semiconductor Industry* (UK: Benn Publications, 1985), p. 12.

The United States accounted for over two thirds of world production of integrated circuits between 1978 and 1985, and more than that in earlier years. Japan has increased its share of world production of integrated circuits from 18 percent in 1978 to 27 percent in 1985. According to the Dataquest estimates, the United States, Europe and Japan produce more than 93 percent of all semiconductors in the

world market for the entire period and more than 98 percent since 1980 (see Table 4).

Table 4. World Production Shares in Integrated Circuits

(in percentages)

Year	USA	Europe	Japan	Rest
1978	68	7	18	7
1979	69	6	18	7
1980	73	6	20	1
1981	72	6	21	1
1982	70	5	23	2
1983	68	6	25	1
1984	67	5	26	2
1985	67	5	27	1

Note: These production shares are based on Dataquest data. See original data through 1983 in Table 3.

Source: *The Semi-Conductor Industry: Trade-Related Issues* (Paris: OECD, 1985), p. 21.

US production of semiconductors grew at an average annual rate of over 26 percent between 1955 and 1983 (see Table 5 below).

A fairly large proportion of semiconductor production in the United States is sold on the open market by merchant firms. Generally speaking, a lower proportion of semiconductors is sold on open markets in Japan and Europe because the firms in those two regions tend to be larger and more vertically integrated than many of the US semiconductor firms. In addition, the end-use of semiconductors differs considerably among the regions. In the United States, the largest market for semiconductors is the one created by computer manufacturing. In Japan, the largest market for semiconductors, at least until quite recently, was created by consumer electronics. In Europe, consumer electronics and telecommunications equipment are the most important customers of the European semiconductor industry.

The structure of demand for semiconductors was a factor of considerable importance in the initial development of the industry in the three regions. In the early days of the U.S. industry, production was

Table 5. Sales of Semiconductors in the United States, 1916-81.
(in millions of dollars)

Year	ICs	Discrete	Total	Growth
1955			39	
1956			89	128.2
1957			140	57.3
1958			202	44.3
1959			388	92.1
1960			532	37.1
1961	5	533	538	1.1
1962	10	525	535	-.6
1963	20	537	557	4.1
1964	51	617	668	19.9
1965	94	742	836	25.1
1966	173	905	1078	28.9
1967	273	787	1060	-1.7
1968	367	762	1129	6.5
1969	498	858	1356	20.1
1970	524	769	1293	-4.6
1971	534	623	1157	-10.5
1972	718	749	1467	26.8
1973	1421	1335	2756	87.9
1974	1767	1347	3114	13
1975	1458	1122	2580	-17.1
1976	2032	1401	3433	33.1
1977	2464	1394	3858	12.4
1978	3261	1589	4850	25.7
1979	4671	1944	6615	36.4
1980	6360	2042	8402	27
1981	6000	2000	8000	-4.8
1982	7100	1600	8700	8.8
1983	8700	1700	10400	19.5
1984	9700	1900	11600	11.5
				25.9
				(ave. growth 1955-84)

Soucre: *Electronic Market Data Book 1982*, Table 4-2

geared to military and space applications. It changed quite drastically when the computer industry displaced government purchasers as the largest source of demand. Computer applications of semiconductors generally required devices which were relatively complex, fast, and ran at cool temperatures. Industrial applications, which figured larger in the early development of the European semiconductor industry, required devices which could handle large amounts of power and which were reliable at high temperatures. Consumer electronics, which were the most important customers for the first Japanese semiconductor producers, generally required devices which used less power than either computer or industrial devices and which have the capacity to handle analog as well as digital signals (i.e. in radios or TVs). As a consequence of the different demand structures, the Europeans did well in power devices, the U.S. did well in developing microprocessors and computer memories with MOS circuitry, and the Japanese did well in CMOS circuits for watches, calculators, and consumer electronics items.[10]

In the mid 1970s, the Japanese perceived that the market was pushing them in the direction of specialization in devices for consumer electronics. Worried that production of consumer electronics would shift to the Third World while the U.S. would continue to dominate the world computer industry, a major effort was undertaken by MITI and the Ministry of Posts and Telecommunications to promote the development of new devices more suitable for advanced information technology. The VLSI Program of 1976-9 was the result, one of the most successful examples of government promotion of technological development after World War II. A major shift has occurred as a consequence of this intervention: the Japanese semiconductor firms were in a much stronger position vis a vis their U.S. competitors by the late 1970s.

While the United States dominated the overall market for semiconductors, Japan lead increasingly in certain key segments. For example, by the end of 1979, the Japanese firms controlled 43 percent of the US market for 16K RAM devices.[11] By the end of 1981, they supplied

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[10] This argument is put forth in Borrus, *et al.*, 1982, *op. cit.*; Giovanni Dosi, *Technical Change and Industrial Transformation* (London: Macmillan, 1984); Francesco Malerba, *The Semiconductor Business* (London: Frances Pinter, 1985).

[11] Michael Borrus, James Millstein, and John Zysman, *International Competition in Advanced Industrial Sectors: Trade and Development in the Semiconductor Industry* (Washington, DC: Joint Economic Committee of Congress, 1982), p. 106.

almost 70 percent of 64K RAM devices in the open part of the US market.[12] In 1984, the Japanese firms introduced 256K RAM chips before a number of major US firms. U.S. firms like Intel, Motorola, Hewlett-Packard and AT&T (Western Electric) still dominated the markets for microprocessors, however, Japanese firms began to eat into this market as well in the 1984-5 period as they introduced their own "state-of-the-art" microprocessors. NEC and Hitachi have been particularly strong in this regard; NEC displaced Texas Instruments in 1985 as the number seller of semiconductor devices in the world.[13]

Semiconductor Production by Specific Firms

Japanese and US firms dominate the markets for semiconductors and integrated circuits, as can be seen in Table 6 below. Only two European firms rank among the top ten firms—Philips and Siemens. While this ranking excludes consideration of captive production of semiconductors (which if included would bring IBM and Western Electric into the list), nevertheless it gives a good indication of market shares in the open market for semiconductors ans the ranking of merchant firms.

The Importance of Merchant Firms in the United States

The distinction between integrated and merchant firms in the semiconductor industry is important because of the absence of predominantly merchant firms both in Japan and Europe. All of the major Japanese firms—NEC, Hitachi, Matsushita, Mitsubishi, Sanyo, and Fujitsu—are integrated in the sense that they are major consumers of their own semiconductor production. Sales of semiconductors on the open market account for less than 20 percent of total sales for NEC and less than 10 percen for the rest.[14] NEC, Hitachi, and Fujitsu have become computer manufacturers primarily, while Matsushita, Mitsubishi, and Sanyo remain primarily manufacturers of consumer electronics. All of them are relatively diversified, however, compared to the merchant firms of the United States.

Table 6. Largest Semiconductor Producers, 1982-4.
(Rank Ordered by 1984 Revenues)

Name of Firm	Country	1982	1983	1984
Texas Instruments	USA	1422	1768	2390
NEC	Japan	1100	—	2350
Hitachi	Japan	800	—	2140
IBM (estimate)	USA	—	—	2000
Toshiba	Japan	680	—	1750
Motorola	USA	1235	1412	1729
Intel	USA	900	1122	1629
Philips/Signetics	Netherlds.	500	—	1150
Fujitsu	Japan	440	—	1070
National Semiconductors	USA	746	785	1030
American Micro Devices (AMD)	USA	358	583	920
Matsushita	Japan	—	—	920
Siemens	Germany	—	—	700
Gould	USA	318	368	435
Harris Corporation	USA	147	151	234

Note: Data are for fiscal years ending on the column year. There is substantial variation in the fiscal reporting systems used by different firms.
Source: Berkeley Roundtable on the International Economy, various publications, and annual and quarterly reports

Semiconductors accounted for over 80 percent of total sales for National Semiconductors, AMD and Mostek, and more than 65 percent for Fairchild and Intel. Texas Instruments and Motorola, the two largest firms in the merchant group, were the most diversified in the sense that they both have kept semiconductors in the range of 30-40 percent of total sales. Texas Instruments branched out into consumer products like calculators and personal computers, while Motorola remains a major producer of communications equipment and consumer products. TI tried to break into the mini- and microcomputer markets as well, although the microcomputer effort was a disaster. There is some evidence that other merchant firms, Intel for example, have been trying to integrate downstream into computers, starting with add-on circuit boards for IBM-PCs and PC-clones and with advanced work

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[12] Gene Bylinsky, "Japan's Ominous Chip Victory," *Fortune* (December 14, 1981), p. 55.

[13] According to Dataquest, NEC sold 1.98 billion dollars worth of semiconductors in 1985 compared with 1.76 billion for Texas Instruments and 1.85 billion for Motorola. See "NEC Tops a List," *New York Times* (January 16, 1986), p. D4.

[14] Borrus, *et al.*, *op. cit.*

stations for the computer industry.[15]

The merchant semiconductor firms have become increasingly candidates for acquisition by more diversified or cash rich electronics firms, and especially computer firms. Xerox has a major stake in Zilog, Siemens owns 20 percent of AMD, IBM bought a 20 percent stake in Intel (recently reduced to 12.5 percent), Philips purchased Signetics, etc. So far this has not reduced the aggressive innovative spirit of the smaller firms, but it may eventually pose such a threat if the trend continues.

Table 7. Top Ten Integrated Circuit Producers in 1983

Company	IC Sales ($ million)
Texas Instruments	1276
IBM	1262
Hitachi	958
NEC	942
Motorola	842
Philips	805
National	783
Fujitsu	692
Intel	655
Toshiba	597

Source: *Trade in High-Technology Products: Industrial Structure and Government Policies* (Paris: OECD, 1984), p. 122.

The integrated electronics, communications and consumer products firms in the United States have realized that semiconductor production is crucial to their competitiveness. While they continue to purchase a large proportion of their needs on the open market, most of them also have developed internal production lines, some of which are also sold on the open market. Hewlett-Packard, a company known for its industrial electronic products as well as for its calculators and small computers, is now one of the leading producers of pruducts and production equipment for very large scale integrated circuits.

Among the mainframe computer manufacturers, IBM stands out as the sole major producer of advanced semiconductor devices. Nobody really knows very much about IBM's production because the firm does not want much to be know about it. IBM employees claim that IBM semiconductors are second to none in quality and that its production technology is the best, at least in the United States.

But IBM has clearly felt a need to go outside to purchase certain devices either because they can be produced cheaper outside or because the fluctuation in internal demand is such that it does not make sense for IBM to produce all of its needs internally. IBM's purchasing of 64K dynamic RAMs on the open market in 1979, for precisely that reason, contributed significantly to the rapid growth of Japanese penetration of the world RAM market. U.S. firms were taken by surprise and were not able to increase capacity as rapidly as Japanese firms. Also, because IBM has a philosophy of disarming its critics abroad by appearing to be a "good citizen" in each country it operates in, the firm frequently purchases components and peripheral devices from national champion firms. Thus, IBM is likely to buy significant numbers of semiconductors from Siemens in Germany, SGS in Italy, Thomson in France, and NEC in Japan. These components are frequently produced under "second source" or licensing arrangements with U.S. firms like Intel. Thus, IBM's desire to avoid political attacks abroad reinforce the tendency of U.S. firms to make second source agreements rather than export their products directly.

Next to IBM, the most important captive producer of semiconductors is the Western Electric subsidiary of AT&T. Since AT&T became a nonregulated firm in 1984, it began to diversify in the direction of computer and telecommunications equipment manufacturing. Now freed to compete on world markets for computers and telecommunications equipment, AT&T is paying more attention to its semiconductor research and production, which has alway been considered one of the most advanced in the world. In is not without significance that AT&T was one of the first firms in the world to announce the successful production of a 1 megabit RAM device.[16] For the mid-range future,

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[15] See also "Intel may soon compete with its customers," *Business Week* (March 22, 1982), p. 63.

[16] Michael Schrage, "AT&T Starts Production of Megabit Chip," *Washington Post* (September 6, 1985), p. B3.

however, AT&T will probably focus most of its efforts on production and marketing of computers and telecommunications equipment.

The European Semiconductor Industry: Strengths and Weaknesses

The European semiconductor industry is yet again another creature. Philips and Siemens remain the major international competitors, and both are relatively diversified electronics firms with computers, telecommunications and consumer product lines supplementing their semiconductor production. Philips has been a particularly innovative firm (it is credited with initial invention of the technology for videorecorders) and has unusually decentralized management system. Philips operates throughout the world as a genuine multinational firm. It sells light bulbs and consumer electronics products on a global basis. Like IBM it has major research and production facilities in all of its major markets, although its largest research center remains in the Netherlands at the headquarters in Eindhoven.

Philips is likely to have some difficulties in the next few years because of its highly diversified markets and its continued strong dependence on consumer items. While Philips was a major innovator in the field of video cassette recorders and compact disk players, its marketing and production skills proved to be less than those of its Japanese competitors.

Siemens is a heavy engineering company primarily and a computer firm secondarily. It is however, a large and diversified firm with a particularly strong research capability. Its relationship with the German *Bundespost* and its linkages with the firms associate with Deutsche Bank (its lead banker) have given it certain advantages in the German domestic market over foreign competitors. The firm has been quite profitable and sits on a sizeable pool of accumulated cash, which it has used on a variety of occasions to purchase firms when it felt it needed to diversify operations in a new direction.

Siemens has been less successful than Philips in keeping up with the state of the art in semiconductors, which has hurt its ability to compete with foreign computer and telecommunications firms. The purchasing of a 20 percent share in AMD was one result of this perceived weakness. So is the more recent cooperation with Philips in the

so-called "Mega Project" to design and produce a 1 megabit dynamic RAM device. The Mega Project has not been very successful. Although a 1 megabit RAM will be produced as a result, it will come on the market later than the offerings of AT&T and the Japanese firms and may not be competitively priced as a result. Siemens strategy for the next few years seems to be focused on the production of chips geared to ISDN (Integrated Services Data Network) applications. Siemens is trying to take advantage of its sheltered position in the German market and its quite substantial technical skills in this technology to create a market niche in these specialized circuits.

Siemens has concluded several agreements with Fujitsu to merchandise Fujitsu mainframe computers under the Siemens label in Europe. It has also formed an alliance with a Japanese robotics firm, Fanuc, to bolster its position in European robotics markets.

Thomson-Brandt in France is an integrated electronics firm, under the turelage of the French government, as is the arms-oriented Matra. Both of these firms were nationalized by the Socialist government of Francois Miterrand in 1981, but they have been left to operate quite autonomously since the resignation of the Jean Pierre Chevenement as Minister of Research and Industry in 1983. Thomson dominates consumer electronics in France, particularly through its Saba television subsidiary, purchased in 1979.

The French government had a third electronics champion called Eurotechnique, which was a joint venture between Saint-Gobain and National Semiconductors. Thomson took over a majority share of Eurotechnique later in 1983, and National Semiconductors was forced to give up its share in Eurotechnique. With the acquisition of Eurotechnique, Thomson was able to produce a full line of advanced microprocessors with Motorola and National Semiconductor designs.

In 1983, the French government sponsored the merger of the telecommunications activities of Thomson (Thomson Telecommunications) with those of CGE (i.e., its daughter firm, CIT-Alcatel). The resulting firm, Thomson-Alcatel, may still not be able to compete with the really big telecommunications equipment firms (like Ericsson, Northern Telecom, AT&T, Siemens, etc.), so the French government is allowing Thomson-Alcatel to make an alliance with AT&T to sell French-made central office switches in the United States in exchange for developing more modern switches jointly for marketing in Europe.

Whereas Thomson, CGE and Alcatel on their own were not internationally competitive in world information technology markets, the combination of these firms at least has the prospect of becoming so. Nevertheless, the French firms will continue to have to make international alliances either within Europe or with American and Japanese firms in order to remain at the technological frontiers of the most important technologies. The perception of the basis weaknesses which lead to this condition is a major source of the support of the French government for European efforts like ESPRIT and EUREKA. More importantly, the French government has sponsored a series of basic research efforts aimed at bringing French technology up to snuff.

The only other European-based firms which are, or have the potential to become, competitive on world markets are Olivetti and SGS-Ates. Olivetti is an office machine firm, based in Italy, which has become more and more a computer manufacturing and marketing concern. It almost failed to make the transition from producing typewriters to making office automation equipment in the mid 1970s, but managed to correct its problems in time. Now it controls roughly half of the European market for office automation equipment. Its efforts to penetrate European microcomputer markets have also been relatively successful. In 1984, Olivetti concluded an agreement with AT&T whereby Olivetti agreed to market AT&T mainframe (Model 3B) computers in Europe in exchange for AT&T's marketing of Olivetti microcomputers in the United States. The two firms also agreed to work together on future computer and telecommunications products.

In February 1984, Olivetti acquired a 49.3 percent interest in a British microcomputer concern, Acorn Computers. Also in 1984 it acquired a majority interest in Sixcom, an Italian engineering company specializing in telecommunications networks for banks. In early 1985, it purchased the European distribution network for Exxon office automation equipment. In other words, Olivetti is likely to remain a highly dynamic and competitive company.

SGS is an Italian firm headquartered in Milan which is owned by STET, a state-owned holding company. SGS makes integrated circuits mainly for military and telecommunications purposes, and has done more than most European firms in staying abreast of the changing technology in semiconductors. Its CEO, Pasquale Pistorio, was formerly employed by Motorola and learned the semicronductor business in Arizona before taking the helm at SGS. SGS opened a plant near Milan in 1981, for the production of MOS (metal oxide silicon) chips. It had operations in Milan, Sicily, Reims, Malta, Malaysia and Singapore by early 1986. SGS was one of the earliest European firms licensed to produce Zilog microprocessors, including the Z-80, which were the main components of the more popular 8-bit microcomputers.[17]

The European producers of semiconductors were clearly in a much weaker position than those in the United States and Japan. They were much more likely to be licensees of U.S. or Japanese firms than vice versa. They had failed to remain at the technological frontier for microprocessors, memory devices, and most VLSI devices. The United States remained dominant in terms of overall market shares, but the Japanese were gaining rapidly, especially in standardized circuits and VLSI devices, including microprocessors. The European firms were much more closely tied to the state for support than those in the U.S. and Japan as a consequence of their weakness.

Trade in Semiconductors: U.S. Deficits, Japanese Surpluses

Analyzing the trade in semiconductors is somewhat complicated by the need to compensate for the fact that many U.S. firms exported semiconductor "parts and accessories" to overseas assembly facilities in Europe, Latin America, and Southeast Asia, and then reimported the assembled devices for sale both in the US and abroad. Most US exports of finished integrated circuits go to Britian, France, the Federal Republic of Germany, and Japan. It has been estimated that the US had a positive trade balance in semiconductor parts and assembled products of 126 million dollars in 1977. The surplus in semiconductors was around 600 million dollars in 1980. By 1984, it was estimated that semiconductor trade produced a deficit of almost 3 billion dollars.[18]

Japan rapidly went from being a net importer of integrated circuits to a net exporter (see Table 8 below). Even the United States became

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[17] "Management American Style at Italy's Microchip Manufacturer," *World Business Weekly* (August 31, 1981), p. 22; Jacob F. Blackburn, "The Telecommunications and Computer Industries in Western Europe," U.S. Department of Commerce, no date but probably February 1986.

[18] Borrus, *et al.*, 1982, p. 49; data from the American Electronics Association as cited in "America's High Tech Crisis," *Business Week* (March 11, 1985), p. 69.

Table 8. Japanese Trade in Integrated Circuits, in Billion Yen

Year	Exports	Imprts	Balance
1973	2.6	33.2	-30.6
1974	6.7	51.1	-44.4
1975	13.5	40.0	-26.5
1976	22.7	62.7	-40.0
1977	31.6	55.7	-24.1
1978	52.3	61.3	-9.1
1979	108.3	98.5	9.8
1980	183.3	108.9	74.4
1981	199.6	114.3	85.3
1982	285.1	127.4	157.7
1983	418.0	144.0	274.0

Source: 1973-77, Daiwa Securities, as cited in Economic Research Associates, 1982, p. 222; 1978-83, *Nomura Electronics Handbook 1984* (Tokyo: Nomura Securities Ltd., 1984).

a net importer of integrated circuits from Japan, with a deficit in 1984 of $900 million. U.S. firms began to complain loudly about the unfair pricing practices of Japanese firms, as RAM prices dropped faster than anyone had expected. Even though U.S. firms still dominated the markets for certain types of integrated circuits, such as microprocessors and ROMs (read-only memories), the RAM devices were an important source of profits and therefore of research and development funds, especially for the more specialized semiconductor firms. These firms found themselves increasingly squeezed from two directions: loss ot market share and inability to put money into developing new types of circuits.

In 1983, the Semiconductor Industry Association threatened to file a complaint under Section 301 of the 1974 Trade Act, but backed down after meetings of the U.S.-Japan High Technology Working Group resulted in agreements to collect more accurate statistics on semiconductor trade and the two sides agreed in principle to grant "equivalent access" to each other's firms.

In June of 1965, a small firm called Micron Technologies headquartered in Boise, idaho, filed an anti-dumping suit against Fujitsu, Hitachi, Matsushita, Mitsubishi, NEC, Oki and Toshiba. It asked that

countervailing duties of up to 94 percent be imposed on these firms retroactively for dumping (selling below the cost of production) of 64K RAM devices. Although a number of SIA members supported the Micron suit, the SIA as a whole remained neutral.[19] A few days later, however, the SIA filed a Section 301 complaint against Japan claiming that they had been denied access to the Japanese market, repeating their earlier charges that the Japanese government had targeted the semiconductor industry and that U.S. firms were suffering the consequences. Apparently, the draft version of the Section 301 complaint called for import restrictions against Japan until U.S. firms were granted access to Japanese markets, but IBM and a number of other larger firms opposed this despite the fact that Intel, AMD, Hewlett-Packard and some of the other mechant firms had favored either import restraints or countervailing tariffs, so the final version did not include this demand.[20]

Table 9. Unit Prices for 256K RAMS

Date	price ($)
Jan 84	38.00
Mar 84	31.00
Jul 84	23.50
Oct 84	17.50
Jan 85	14.00
Mar 85	9.75
Jul 85	4.75
Oct 85	2.75
Jan 86	2.10

Source: *Infoworld* (February 3, 1986), p. 1.

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[19] Andrew Pollack, "Japan Seen Target of Chip Plea," *New York Times* (September 28, 1985), p. 21.

[20] Jack Robertson, "STA Bid to Hit Japan on Trade Disputed," *Electronic News* (June 24, 1985), p. 1; "The Bloodbath in Chips," *Business Week* (May 20, 1985), p. 63.

On September 30, 1985, Intel, AMD and National semiconductor filed an anti-dumping complaint against eight Japanese firms for dumping EpROMs (eraseable programmable read-only memories). The complainants claimed that the Japanese were selling these devices at 77 to 227 percent below fair value, and that production costs were at least 6 dollars per device while U.S. selling prices were 4-5 dollars.

The International Trade Commission ruled that the U.S. industry had been injured by the trade practices of the Japanese firms in all three cases. The ruling on 64K RAMS was made in August, and on EpROMs in November, but a ruling on 256K (and above) RAMs was made in January 1986 after an unusual and unprecedented intervention in the process by the President and the Secretary of Commerce. Apparently, someone in the Reagan Administration became convinced of a need to accelerate the process behind the RAM complaint and to change the nature of the complaint somewhat to provide greater bargaining leverage with the Japanese government.

On December 16, 1985, Secretary of Commerce Malcolm Baldridge announced that the Department of Commerce was initiating its own investigation into the possible dumping of 256K RAMs at the request of the President. On March 14, 1986, Commerce ruled that Japanese firms had indeed dumped 256K RAMS and 1 Megabit RAMS and that the dumping margins for at least two firms, Mitsubishi and NEC, exceeded 100 percent. Commerce had ruled similarly on 64K RAMS in January, so the second ruling was not much of a surprise. Nevertheless, the conversion of the Section 301 complaint into an anti-dumping complaint and the speed with which the two anti-dumping investigations were carried out signalled the intent of the Reagan Administration to make trade in semiconductors a major thrust in its trade diplomacy with Japan.[21]

The Japanese government responded to the changed mood in Washington first by sending MITI officials to meet with industry representative on January 20, 1986. At this meeting, MITI offered to establish floor prices for devices sold by Japanese firms in the United States. The U.S. firms rejected this offer claiming that it would still allow the Japanese to dump in third country markets and thereby give U.S. equipment firms large incentives to locate their production outside the United States. In addition, they claimed that floor prices would violate antitrust laws. What they wanted, they said, was for Japan to stop dumping on a worldwide basis.[22]

Another Japanese response to the trade dispute was for the firms to raise prices independently.[23] Hitachi also announced a special program to increase imports of electronic components and other items in the United States and to increase contributions to the U.S.-based Hitachi Foundation. But most U.S. observers considered this to be mere window dressing. The appreciation of the yen against the dollar in the first months of 1986 was expected to help somewhat in reducing trade tensions overall, but not much relief could be expected in semiconductors because the underlying source of the dispute was the global overcapacity which resulted from an investment boom in the late 1970s and early 1980s.

Overcapacity

A general downturn in the computer industry in 1984 led to a slashing of semiconductor inventories by 36 percent in 1985. The demand for semiconductors declined sharply and producers responded by cutting prices in order to compete for the remaining demand.[24] But besides this general drop in demand corresponding to a cyclical downturn in computers and other types of electronic equipment, a general overcapacity problem had been developing in world markets. One research firm estimated that by late 1985 worldwide demand was approximate 40 percent of production capacity in the semiconductor industry. Overly ambitious sales projections and government programs designed to aid weaker firms led to an "orgy" of capital spending in the early 1980s. Chipmakers invested 6 billion dollars in plant and equipment in 1984 (remember that total sales during that year were around 21 billion).

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[21] Clyde Farnsworth, "U.S. Plans Inquiry on Japanese Chips," *New York Times* (December 7, 1985), p. 43; Stuart Auerbach, "Tougher U.S. Stance Seen On Chips," *Washington Post* (December 5, 1985), p. E3; "Cutting Rough with Japan's Chip Markers," *The Economist* (January 11, 1986), p. 59; Clyde Farnsworth, "New Chip Ruling Goes Against Japan," *New York Times* (March 14, 1986), p. D2.

[22] Jack Robertson, "Japanese Officials Visit IC Cos. on Dumping," *Electronic News* (January 20, 1986), p. 12.

[23] Susan Chira, "Japanese Raising Chip Prices," *New York Times* (December 4, 1985), p. D1.

[24] John Wilson, "The Chips May Not Be Down Much Longer," *Businee Week* (December 16, 1985), p. 26.

They invested another 4.5 billion in 1985 despite the turndown in demand.[25]

Unless demand recovers in an unprecedentedly spectacular way, there will continue to be a crisis of overcapacity leading to pressures for capacity reduction. The key question politically is where the capacity reductions will occur and who will pay the cost of the reductions. Thus, one could see the U.S.-Japanese trade dispute of 1985-6 as an initial battle in what would become a much uglier trade war. The signs were not good. The U.S. Department of Defense was undertaking a series of studies to deal with growing "dependence" on foreign suppliers for vital electronic components. Important U.S. firms like Intel, Texas Instruments, Motorola, AMD were losing money and dropping production lines in certain products. Mostek was nearly liquidated before its purchase by Thomson-CSF. Even the computer and telecommunications equipment manufacturers in the U.S. were beginning to worry. Their interest in being able to buy cheap components was being weighed against their interest in being assured access to the most advanced devices (particularly worrisome in light of the growing strength of Japanese computer and telecommunications firms).

Summary and Conclusions

The semiconductor industry has been a dynamic industry, both in terms of technological change and in its pattern of economic growth. It has not been immune from cyclicalities experienced by other industries, as has been graphically demonstrated by the last two years. It remains, however, one leading contemporary example of the general dynamism of information technology and of the problems created for international economic relations by the sensitivities of nations to dependence on others for what they define to be strategically important goods. The early lead of the United States in semiconductors provoked responses in Europe and Japan. In Europe, the initial response was to back national champions like Ferranti, Thomson and Siemens. Now that response is widely perceived to have failed, leading therefore to new efforts at the European level like ESPRIT and EUREKA. In Japan, the VLSI Project was the response, and the result was a dramatic improvement in the competitiveness of Japanese firms in international competition.

The organization of production in the United States made it possible for smaller merchant firms to develop alongside larger integrated firms like IBM, AT&T, and Motorola. The conditions which favored the rise and growth of the merchant firms appear to have changed radically. The increasing investment required for the development and production of new devices, the intense competition from integrated electronics firms in Japan and Europe, and the greater ability of large U.S. firms to get access to the capital needed to keep up with that competition seem to have greatly undermined the once nearly unassailable position of the merchant firms. Their response has been to turn to trade policy remedies to buy time for restructuring. In all likelihood, this response will not prevent the trend toward further incorporation of the smaller semiconductor firms into industrial groups through acquisitions, equity participation and other forms of alliance. Public policy remains very important in providing sources of assured demand for products, subsidies for R&D and capital investment, and trade policies which insulate the domestic market or provide greater access to foreign markets. But not all countries are equally good at delivering public policies that aid semiconductor producers. The Japanese have been unusually effective compared to both Europe and the United States. The result is like to be increasing tension in U.S.-Japanese and Euro-Japanese relations over the next decade.

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[25] Bro Uttal, "Who Will Survive the Microchip Shakeout," *Fortune* (January 5, 1986), p. 82.